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QUANTITY AND CHARACTER OF CREOSOTE IN WELL-PRESERVED TIMBERS.

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INTRODUCTION.

The practice of preserving timber by impregnating it with antiseptics is spreading rapidly in the United States. Engineers and business men are recognizing more and more fully that, largely because of the increasing scarcity of good timber and its higher price, timber preservation is a paying investment.

Of the various preservative processes which have been devised, those using coal-tar creosote have proved the most efficient. In the long run they are also frequently the most economical, the longer service offsetting the greater first cost as compared with processes using metallic salts. Moreover, creosoted wood can be used for some purposes, as for piles set in salt water, for which wood treated with metallic salts is but slightly more durable than untreated timber.

Recent reports on the service of creosoted railroad cross-ties, and of piles placed in salt water, have clearly shown that, while proper treatment gives remarkably good results, much of this timber was not properly treated and has not lasted as it should. On the other hand there is abundant evidence that the growing use of creosote, and the fact that creosoting means the investment of considerable capital in the expectation of a good return through the increased life of the timber, makes it imperative that we should know, as completely as possible, just what constitutes efficient creosote treatment.

The efficiency of treatment will depend on three things—the amount of creosote, its character, and the thoroughness with which the timber is penetrated. The proper amount of creosote will depend upon the intended use of the timber. Piles, for instance, which must resist the attacks of marine borers, need more creosote than telephone poles; and piles in warm waters require more than those in cooler waters. The sort of creosote best suited to prevent decay and the inroads of marine borers can be ascertained only by many careful experiments. The proper means for securing a maximum penetration is an engineering problem, complicated by many factors, such as the differences of wood structure or the moisture content of the timber.

There are many ways of approaching this problem. One of the most promising is a study of the nature of the creosotes present in timbers which have given long service. The results of a series of analyses of the oils present in such timbers forms the most important part of this paper. A brief account of the source and composition of coal-tar creosote precedes the description and discussion of the experiments.

MANUFACTURE AND COMPOSITION OF CREOSOTE.

SOURCE AND COMPOSITION OF COAL TAR.

When certain varieties of coal are heated in an oven or retort, in the absence of sufficient air for their combustion, the coal is decomposed and gas, tar, and coke are formed. The gas and tar rise from the heated mass and the coke remains in the retort. Coke and illuminating gas are manufactured in this way. Where coke is the main product the "beehive" oven is used and the gas and tar are not collected, but when the volatile materials are to be collected the "by-product" oven is used. In making illuminating gas the coke and tar are regarded as by-products, and one of the problems of management is how to dispose of these by-products advantageously.

Coal tar is an extremely complex mixture of organic compounds of which the composition is by no means constant, but varies not only with different coals but also with different treatments of the same coal. The same coal will yield at the same plant various qualities of coke, gas, and tar, depending on the amount of heat applied, the quantity of air admitted, and the season of the year. When a low heat is applied a relatively small amount of gas and tar is evolved and the tar contains large quantities of compounds belonging to the paraffin series. On the other hand, with a high temperature much larger amounts of gas and tar are obtained and the predominant compounds of the tar, in nearly all cases, are those belonging to the aromatic series, such as benzene, toluene, phenol, naphthalene, anthracene, etc.

THE PRODUCTION OF CREOSOTE FROM COAL TAR.

The first distillation of crude tar, in which several separate fractions are usually taken, is made in large iron retorts holding from 10 to 30 tons. The forms of the retorts and the manner of controlling the distillation vary more or less in different works. In some cases the still is provided with a thermometer inclosed in an iron tube screwed into the still head; in other cases the time for changing the receiver for various fractions is judged solely by the specific gravity and other properties of the distillates. The separation aimed at is more or less accurately attained in both ways.

In Germany the fractions are frequently taken as follows: The temperature is that registered by the thermometer in the tar at the beginning of the distillation, but free from the oil and indicating the temperature of the vapor passing over when anthracene oil begins to distill.

First light runnings up to	110° C.
Light oils	110° to 210° C.
Carbolic oils	210° to 240° C.
Heavy or creosote oils	240° to 270° C.
Anthracene oils	270° to 400° C.

At many English works the following fractions are taken with the thermometer placed as in the German procedure just cited:

Light naphtha up to	110° C.
Light oil	110° to 170° C.
Carbolic oils	170° to 225° C.
Creosote oils	225° to 270° C.
Anthracene oils	270° to 360° C.

These temperatures are by no means universally accepted in the respective countries, and one or more fractions are often omitted; when, for example, it does not pay to extract carbolic acid, or when the demand for anthracene is limited.

Owing to the variable constitution of the tar and to the different temperatures between which fractions are taken, the products of this preliminary separation are frequently widely different in physical character and chemical composition.

In distilling according to the German method given above, the "first runnings" and "light oils" contain, among other things, benzene, toluene, and the xylenes; the "carbolic oils" contain phenol, the cresols, and some naphthalene; the "creosote oils," small quantities of phenols, naphthalene, anthracene, and many other hydrocarbons; the "anthracene oils," anthracene, acridene, etc. The residue in the still is either soft or hard pitch, according to the point at which the distillation is stopped. When the anthracene oil is completely distilled the residue is largely hard pitch or carbon, and this is used as a briquette binder and in the manufacture of electric-light carbons. When the distillation is stopped at an earlier stage soft pitch is obtained which contains a considerable quantity of the high-boiling tar constituents, and is used for roofing and for builders' papers.

At present there is almost no market in America for hard pitch, whereas the demand for roofing pitch is very great. This demand for soft pitch, together with the lack of an American market for anthracene, explains why the distillation of tars is not carried so far here as it is at some of the foreign works.

STATISTICS OF THE PRODUCTION AND IMPORTATION OF CREOSOTE.

In 1898 there were produced at gas works in the United States 24,384,798 gallons of coal tar, valued at $902,400, or 3.7 cents per gallon. In the same year about 4,023,000 gallons of coal tar were produced by 520 " by-product " coke ovens, the total product for the year being 28,407,798 gallons.[a]

In 1903 the total amount of tar produced amounted to 62,964,393 gallons, valued at $2,199,969, or 3.49 cents per gallon. This includes the tar produced at 1,956 " by-product " coke ovens. There are no reliable figures showing what part of this total was produced at these " by-product " ovens, but the amount of coal coked at such ovens in that year was 2,605,453 tons.[a] The average yield of tar per ton of coal for the year 1903 was a little over 10 gallons.[a] The averages for the gas works and by-product ovens, separately, however, differ from the general average, the former for that year being about 12.5 gallons per ton and the latter about 8.5 gallons. Therefore it follows that approximately 22,150,000 gallons of coal tar were produced at " by-product " coke ovens in the United States in 1903. This leaves approximately 40,800,000 gallons as the production of gas works for this year.

In 1904 the total production of coal tar amounted to 69,498,085 gallons, valued at $2,114,421, or 3.04 cents per gallon. Of this amount, 27,771,115 gallons were produced in " by-product " coke ovens and 41,726,970 gallons at gas works.[a]

In 1905 the total amount of tar produced was 18,022,043 gallons, valued at $2,176,944, or 2.73 cents per gallon. Of this amount, 36,379,854 gallons were produced in by-product coke ovens and 43,642,189 gallons at gas works, so that the output of by-product coke ovens increased considerably over that of the previous year, while the output of the gas works remained nearly stationary.[a]

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[a] Annual Reports, U. S. Geological Survey.

No reliable figures are obtainable showing how much coal tar is distilled in this country. Practically all of the by-product tar is distilled and approximately one-half of the total tar made at gas works. It is safe to say that at least 40,000,000 gallons of tar were distilled in the United States in 1903. If, then, we assume that the average coal tar produced in this country contains at least 10 per cent of oils which can be used as, or added to, creosote oil, it follows that the production of creosote oil in the United States in 1903 was approximately 4,000,000 gallons.

Making similar estimates from the statistics of the production of coal tar in 1904 and 1905, it is safe to say that at least 4,850,000 gallons of creosote oil were produced in this country in 1904 and at least 5,800,000 gallons in 1905.

In 1903, 3,711,565 gallons of creosote oil, valued at 5.8 cents per gallon, were imported into this country. In 1904 the importation amounted to 3,783,472 gallons, valued at 6.3 cents per gallon. In 1905 it was 7,750,531 gallons, valued at 5.4 cents per gallon.[a]

It would therefore appear that about 7,700,000 gallons of creosote oil were used in this country in 1903 for the impregnation of timber, that in 1904 the amount used was approximately 8,650,000 gallons, and that in 1905 approximately 13,550,000 gallons were used.

COMPOSITION OF COMMERCIAL CREOSOTE.

Technically speaking, the fraction of oil passing over between 240° C. and 270° C. during the first distillation of the crude coal tar is known as " creosote oil," " heavy oil," or " dead oil of coal tar." In practice, however, the oily residues which remain after extracting carbolic acid, napthalene, and anthracene from the various distillates in which they occur are added to the creosote oil, and, in consequence, many of the creosote oils of commerce contain considerable amounts of materials having boiling points higher than 270° C. and lower than 240° C. As a matter of fact, it is the practice at nearly all distilling plants to add to the " creosote well " or tank all those oils and residues which can not profitably be worked over and used to greater commercial advantage.

The solvents which are used in the purification of napthalene and of anthracene are sometimes added to the " creosote well," and this accounts for the occasional presence of paraffin oil in creosote.

The " creosote well " or tank is usually constructed of steel plate, and is fitted with inclosed steam coils at the bottom, in order that the solid materials crystallizing out can be melted before the oil is delivered to tank cars, tank steamers, or barrels. A stirring device is also frequently made use of to secure uniformity in the quality of the supply obtained from any one storage tank from which frequent deliveries are made.

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[a] Annual Reports of Commerce and Navigation for 1904 and 1905, Department of Commerce and Labor.

The creosote oil of commerce contains phenol (carbolic acid), the ortho, meta, and para cresols, naphthalene, the α and β methylnaphthalenes (the former being a liquid, the latter a solid melting at 33° C.), anthracene, phenanthrene, acridene, and small quantities of certain high-boiling bases and acids. When first distilled, creosote has a distinctly fluorescent appearance, and is light green in color. There is strong evidence for the belief that some of the individual constituents in creosote oil combine with each other and probably form new products.

At certain works carbolic acid is extracted, and the creosote oil coming from such places is low in "tar acids;" at other places, naphthalene is of considerable commercial importance, and the creosote oils obtained from these works contain little naphthalene. Usually anthracene separates with naphthalene, and in the event that the latter is frozen out, the former is also lacking in the oil which is placed on the market. In America the creosote oils usually contain large amounts of naphthalene, very small amounts (about 5 per cent) of phenols or cresols, and practically no anthracene. Little anthracene oil is found in the average specimen of creosote oil made in the United States for the reason already mentioned, namely, that in forcing the distillate to a temperature at which anthracene oil passes over, the soft pitch is ruined for roofing purposes, and a hard pitch, which is of practically no commercial importance in this country, is obtained.[a]

It is evident that these variations in manufacture result in creosotes differing greatly in physical and chemical properties. Some commercial creosotes are rather thin oils, some are almost entirely solid with naphthalene, and some are heavy oils with a large proportion of high-boiling constituents.

The different sorts of oils are believed to have different preservative values when injected into timber, but there is, unfortunately, a lack of uniformity in opinion. Some investigators have advocated oils rich in phenols, some those containing much naphthalene, some those containing a maximum of the high-boiling compounds. But little has been published on the subject.

ANALYSES OF THE CREOSOTE EXTRACTED FROM TIMBER WELL PRESERVED AFTER LONG SERVICE.

To determine what is, in fact, a good oil, a natural way is to examine the composition of those oils which have protected treated timber satisfactorily. This can be done by extracting and analyzing the oils from timbers the exact history of whose service is known.

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[a] For a more extended discussion, see Lunge's Coal Tar and Ammonia.

The writer secured from various sources a number of creosoted timbers which had been in varied and extended use under markedly different climatic conditions. The method of extracting and analyzing the oils from these timbers is given below.

METHOD OF EXTRACTING CREOSOTE FROM TIMBER.

As soon as a specimen of creosoted wood was received it was placed in a turning lathe, and cuts about 0.02 inch in thickness were made with a sharp tool, the lathe running slow enough to prevent the generation of such heat as experience showed would volatilize the oil. If the specimen was too small for the lathe, borings were made with a 1-inch auger. In every case, however, the volume of wood worked up into a fine condition for extraction was accurately determined.

The cuttings or borings were then placed in large extractors (fig. 1), and extracted with absolute alcohol, and subsequently with anhydrous benzene. To prevent the iron of the extractors from combining with the tar acids, their interior was heavily lined with pure tin, a metal which experiment showed to be unaffected by tar acids. When the extraction was complete, the extract was filtered and the alcohol and benzene were distilled off in turn. In this removal of the solvents, use was made of a large Hempel column filled with glass beads, or of a Le Bel and Henninger tube. It was found that when these aids to fractionation were not used napthalene would volatilize with the vapors of alcohol and benzene.

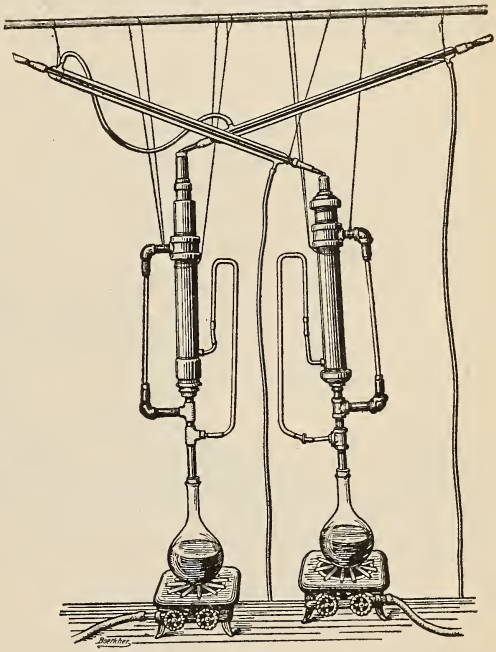

FIG. 1.—Apparatus for extracting creosote from wood cuttings.

The only troublesome materials which this extraction could remove from the wood, and so contaminate the creosote, were the eleo-resins.

Although it is possible to separate these compounds from creosote, this involves more error than disregarding them entirely.

The amount of oil obtained from each specimen is stated in terms of anhydrous creosote per cubic foot of timber. The actual cubic content of each specimen analyzed was accurately determined, and this, together with the weight of creosote oil obtained from it, formed the only basis of the calculations employed. The result of the estimation of the content of creosote was confirmed in every case by an analysis made in the ordinary glass Soxhlet extraction apparatus. The results obtained with the two sets of apparatus agreed to within less than one-half pound to the cubic foot. The results given in the table on pages 14 to 16 are the average of the two determinations.

METHOD OF ANALYZING THE EXTRACTED CREOSOTE.

The analytical tests commonly believed to give the most information concerning creosote were applied to the extracted oils. A fractional distillation is the most important of these tests. The extracted creosotes were therefore fractioned, and when the precipitates of solid naphthalene and of anthracene oil [a] were noticeably large the amounts of these deposits were determined. The percentage by volume of tar acids was also estimated. The specific gravity was not determined, since a very slight admixture of resin causes a marked change in specific gravity.

FRACTIONAL DISTILLATION.

Of the different methods used in analyzing the extracted oils, the one selected, after a series of preliminary tests, appeared best suited for the work in hand.

Figure 2 shows the apparatus used in making fractional distillations.

The distilling vessel was the side-neck flask of Jena glass. The outlet tubes of the flasks used were placed rather below the middle of the neck, and, to insure a good condensation and prevent the ignition of the first part of the distillate, these delivery tubes were 40 cm. long. Retorts were not used because the fractions obtained from these vessels are much less sharply defined. In place of the usual Bunsen burner, a Rogers burner was employed, as the flame is under better control and the contents of the distilling flask less likely to bump or froth. During distillation the flask was placed on a thick asbestos board through which a hole about 1½ inches in diameter had been cut. This asbestos sheet prevented the radiation of heat from the burner to the thermometer. A mica shield was placed around the distilling bulb whenever protection from draft was necessary.

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[a] Anthracene oil is here used in the commercial sense; its oil contains other solids besides anthracene.

The thermometers used were made of Jena normal glass and filled with nitrogen. To guarantee their accuracy, they were carefully compared with a set of Anschütz standard thermometers. They were always so placed that their bulbs were just below the outlet tube, so that the temperature recorded at any moment was that of the vapors passing over.

Two hundred and fifty grams of oil were used for each distillation. The fractions were caught in small flasks which had been previously cleaned, dried, and weighed. The amount of each distillate was determined by a second weighing taken after the fraction had cooled.

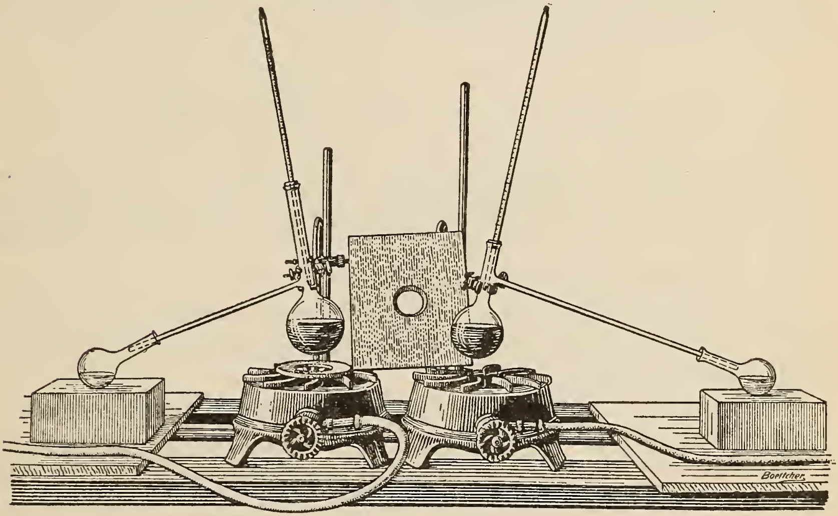

Fig. 2.—Apparatus used in making fractional distillations.

When a complex mixture such as creosote is distilled the various distillates passing over do not volatilize at the exact boiling point of the individual compounds which they contain, and the compounds can not be separated in the pure state except by repeated distillations. If all creosote oils were similarly constituted, then, by means of a series of analyses, it could readily be determined at what temperatures the various constituents volatilize; but since oils vary greatly in composition, this is not possible; such temperatures as are determined upon for the separation of the various fractions are, in a measure, arbitrary. For instance, if an oil is rich in naphthalene and also contains a certain amount of material distilling below 200° C., some of the naphthalene is liable to volatilize with the lighter oil, and it will have entirely passed over when a temperature of 245° C. is reached. On the other hand, if the oil contains a large amount of the higher-boiling constituents, such as anthracene, and also a considerable amount of naphthalene, the latter is frequently not gotten rid of before a temperature of 250° C. is reached. The point at which naphthalene ceases to come off, if it is present, can be determined by allowing a drop of the distillate supposed to contain it to fall on a piece of cold porcelain. If the drop solidifies, the presence of naphthalene is shown.

In over 800 distillations conducted by the writer it was found that 92 per cent of those oils which contained naphthalene gave it off between 205° C. and 245° C., and one of the fractions has consequently been taken between these temperatures.

After conducting tests on a great many oils the writer was of the opinion that the most information could be obtained by separating the distillates as follows:

1. To 170° C.
2. 170° C. to 205° C.
3. 205° C. to 245° C.
4. 245° C. to 270° C.
5. 270° C. to 320° C.
6. 320° C. to 420° C.
7. Residue above 420° C.

Fraction No. 1 contains the light oil and water. In case much water is present some of the naphthalene will frequently volatilize with it.

No. 2 should contain phenol and the cresols.

No. 3 contains naphthalene and the two methylnaphthalenes; these bodies crystallize out, and by filtration the amount of solid naphthalene can be determined.

No. 4 contains, among other compounds, dimethylnaphthalenes.

No. 5 was usually entirely liquid on cooling, and its composition is complex and variable. In case little anthracene oil is present, some of it will be found in this distillate.

No. 6 usually contains anthracene oil, phenanthrene, acridene, etc., and solidifies on cooling.

The residue above 420° C. may contain practically the same as No. 6, and also tar.

DETERMINATION OF TAR ACIDS.

"Tar acids" is a technical term used to denote all those creosote constituents which contain hydroxyl groups. The known compounds of this sort occurring in creosote are phenol or carbolic acid; the ortho, meta, and para cresols, usually termed cresylic acids; α and β naphthol, and the xylenols.

The method of estimating the tar acids is based on the following reactions: When a phenol—as, for example, carbolic acid—is treated with sodium hydroxide solution, the water-soluble sodium phenolate is formed, thus:

$$C_6H_5OH+NaOH=C_6H_5ONa+H_2O.$$

On treating this sodium phenolate with a mineral acid the salt is broken up and the original phenol recovered, thus:

$$2C_6H_5ONa+H_2SO_4=2C_6H_5OH+Na_2SO_4.$$

In using these reactions to estimate tar acids in creosote it is convenient to distill 100 cm³ of oil until a temperature of 420° C. is reached, collecting the distillate in one vessel. This oil is extracted with 40 cm³ of sodium hydroxide solution of 1.15 specific gravity, the mixture being warmed and frequently shaken. The oil and the aqueous solution are separated in a separatory funnel, and a second and third extraction made, using 30 and 20 cm³, respectively, of the sodium hydroxide solution. The three alkaline extracts are united in a 200 cm³ graduated cylinder, and the solution is acidified with dilute sulphuric acid. The mixture is then allowed to cool and the volume of tar acids noted.

RESULTS OF THE ANALYSES.

The results of the analyses of the creosote extracted from 37 different samples of wood are given in the Appendix. The majority of these samples were obtained from various English companies using creosoted wood. Such details as could be learned concerning the history of the timbers are given in the footnotes.

A clearer comprehension of the analytical results may be had by dividing the timbers into several classes and comparing the average figures in the various groups. The 37 samples may be divided into six classes: Railroad ties, including eighteen English samples and one American sample; English piles; American piles; paving blocks showing good service, two English and two American; one sample of American paving block showing poor service, and one conduit pipe. The average results in each of these groups and the general average of all the well-preserved timbers are given in the table below:

Analyses of extracted oils.

Samples.	Average service.	Creosote to the cubic foot.	Distillation of extracted oil.								
			To 205°.	205° to 245°.	245° to 270°.	270° to 320°.	320° to 420°.	Residue above 420°.	Solid naphthalene from distillates.	Solid anthracene oil from distillates.	Tar acids.
	Years.	*Pounds.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Cm³.*
19 cross-ties.........	21.84	9.58	0.025	12.07	13.88	23.80	24.69	25.27	1.19	23.47	0.65
6 English piles	43.00	9.19	.46	16.92	15.31	21.06	22.77	23.04	....	19.95	.61
6 American piles ..	20.20	15.64	.57	30.28	15.82	18.49	13.21	21.43	25.93	43.27	......
4 paving blocks....	23.60	15.70	.29	21.34	21.39	18.73	19.40	18.64	12.52	40.40	.52
1 paving block, poor service.....	9.00	5.77	9.62	14.41	19.27	41.74	11.23	3.40	....	....	......
1 conduit pipe.....	14.00	8.74	5.08	27.23	10.46	27.68	19.03	9.93	23.17	14.28	......
Average of 36 timbers giving good service............	24.90	11.18	.36	17.37	15.18	22.00	21.71	23.09	6.98	27.81	.50

DISCUSSION OF THE ANALYTICAL RESULTS.

QUANTITY OF OIL FOUND.

The average figures show that the quantity of creosote in these long-service timbers was not excessive. It is an unfortunate circumstance that we know practically nothing of the amount of oil which was injected into the various samples. Six of the ties, Nos. 8, 9, 104, 106, 109, and 113, were said to have received 2½ (English) gallons of creosote each. Assuming that the creosote had a specific gravity of 1.05, and that the ties contained at least 2½ cubic feet of wood, it would appear that these timbers received 10.50 pounds of oil to the cubic foot. The average amount present was 8.56 pounds.

The American piles show a much higher content of oil than the English samples. It should be noted that the American piles were all set in warm water, those farthest north being on the Virginia coast.

There is a considerable contrast between the quantity of oil present in the paving blocks which gave good service and the sample which was short lived. It is impossible to say which was the more important factor in determining this difference in service—the quantity or the quality of the injected creosote. Very likely it was a combination of both factors.

In general the results tend to show that 10 pounds of creosote per cubic foot is ample for railroad ties, and that piles require from 10 to 20 pounds, according to the location in which they are to be placed. If a creosote contains much light oil, a proportionately larger quantity must be used.

CHARACTER OF THE EXTRACTED CREOSOTE.

A difficulty in the proper interpretation of the results of the analyses arises from our ignorance of the quality of the oil used in treating the various timbers. It is, therefore, possible to believe that the materials which have volatilized from the timbers have created an antiseptic environment which has been a most important factor in preserving the wood.

Notwithstanding this legitimate query concerning the possible efficacy of the substances which have disappeared, the analyses furnish a strong argument in favor of the use of heavy oils. Tie No. 112, for example, had seen but fourteen years' service, two-thirds the average of the ties, and doubtless would not have suffered decay for many years to come, yet it does not contain more light oil than the average of the tie group, but, on the contrary, the creosote from this specimen was over half recovered as solid anthracene oil. If the constituents present in the timbers represented a nonefficient residue from which the effective light oils had evaporated, we should expect to find a relatively high proportion of light oils in this tie which had seen a shorter term of service. The natural interpretation of the results is that it is the heavy, high-boiling compounds which stay in timber and are an efficient barrier to the entrance of water and to the attacks of fungi and borers.

The creosotes recovered contained practically nothing which boiled below 205° C. The general average shows that 32.9 per cent of the oils distilled below 270° C. and 66.95 per cent above—that is, two-thirds above and one-third below this rather high temperature. Another noticeable fact is the large amount of solid anthracene oil recovered from the distillates of many samples, the highest being 57 per cent.

A distinctive feature of the creosotes from American piles was the quantity of naphthalene which they contained. The average from this class of timbers was nearly 26 per cent, and one sample showed over 48 per cent. It appears probable that the creosotes used in treating these timbers contained much more naphthalene than the oils applied to the English piles. The results indicate that this substance possesses value for timber treatment, although it probably is inferior to anthracene oil. It is worth noting that these long-lived American piles contained more anthracene oil than naphthalene.

Perhaps the most striking thing is the disappearance of the tar acids. It is certainly conservative to place the original tar-acid content at 5 per cent. Yet the extracted oils showed but a tenth of this amount. It is possible that these compounds, on account of their hydroxyl groups, have undergone chemical changes during the many years that they have been exposed to varying amounts of water and air, to the reactive lignin portion of the wood, and to the numerous compounds present in creosote. On the other hand, these phenol bodies may have volatilized or been washed from the timbers.

It appears, therefore, that light oils, boiling below 205° C., will not remain in timber, but that heavy oils, containing a high percentage of anthracene oil, will remain almost indefinitely and protect the wood from decay and boring animals. It is probable that naphthalene stays in wood for many years, but whether it is as valuable as anthracene oil is open to question. The value of the tar acids has apparently been overestimated by many persons, for although it has not been proved that they are valueless, they have been shown to possess poor staying qualities.

APPENDIX.

RESULTS OF ANALYSES.

Analyses of extracted oils.

Sample.	Source.	Species.	Service.	Creosote per cubic foot.	Distillation of extracted oil.							Solid naphthalene from distillates.	Solid anthracene oil from distillates.	Tar acids.
					To 205°.	205° to 245°.	245° to 270°.	270° to 320°.	320° to 420°.	Residue above 420°.	Total.			
			Years.	*Pounds.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Cm³.*
Tie No. 106	Glasgow and Southwestern Rwy., Scotland.	Pine	16	4.06		16.32	13.24	20.15	24.10	25.93	99.74			0.51
Tie No. 104	do	do	18	9.24		9.37	18.17	27.54	21.38	23.01	99.47			.36
Tie No. 113	do	do	18	8.01		9.75	18.54	24.96	22.42	24.07	99.74			1.13
Tie No. 109	do	do	16	8.29		7.08	12.45	16.68	40.84	22.52	99.57			.74
Pile No. 118	Great Western Rwy., Heath Division, England.	Yellow pine	47	7.68		19.92	17.58	20.62	14.48	27.11	99.71		32.15	.78
Tie No. 107	do	Baltic redwood.	42	12.71		9.45	12.30	27.56	33.48	17.87	100.66		51.07	.96
Tie No. 105	do	do	a 33	5.08		6.83	10.16	26.11	32.17	23.91	99.18			
Tie No. 103	London and Northwestern Rwy. Co., England.	do	19	14.07		17.78	11.88	21.26	14.64	34.01	99.57		35.14	.26
Tie No. 110	do	do	19	13.84		18.23	16.61	23.01	12.78	29.11	99.74		26.87	.68
Paving blocks Nos. 88 and 89.	Northeastern Rwy. Co., England	Yellow pine	20	17.19		20.13	10.27	12.18	27.46	29.78	99.82	21.46	57.03	1.19
Tie No. 114	do	Pine	30	7.41		15.44	7.44	15.68	44.96	16.14	99.66			.37
Paving blocks Nos. 90 and 91.	City Engineer, Hull Corporation, Hull, England.	Yellow pine	11	14.37		21.03	24.45	7.68	25.06	21.78	100.00	24.93		.87
Tie No. 108	Maryport and Carlisle Rwy. Co., England.		23	5.17		10.59	12.61	28.56	20.32	27.87	99.95			.62
Tie No. 2	Highland Rwy. Co	Scotch fir	20	5.93		15.78	8.04	27.80	18.12	29.81	99.55		48.14	.76
Tie No 3	do	do	20	9.03		10.15	16.32	20.54	12.63	40.02	99.66		52.13	.54
Tie No. 41	do	do	22	12.76		10.46	20.34	22.63	16.32	29.83	99.58			1.14
Tie No. 101	North British Rwy. Co., Scotland	do	24	11.46		8.32	26.36	23.42	29.58	11.86	99.54		40.15	.38
Tie No. 102	do	do	21	8.19		18.24	12.16	28.92	22.76	17.35	99.43			.21
Tie No. 112	do	do	14	7.21	0.47	7.65	8.03	17.58	38.88	27.97	100.58		53.04	1.23
Pile No. 116	Clyde Navigation Trust, Glasgow	Red pine	46	8.42		9.44	16.92	29.68	32.08	11.03	99.15			
Pile No. 111	do	do	46	8.07	2.76	19.53	14.61	18.15	17.23	27.03	99.31			
Pile No. 117	do	do	46	9.31		22.20	20.10	24.30	16.24	16.84	99.68		33.14	
Pile No. 4	do	do	46	12.61		16.87	12.15	13.25	25.37	32.30	99.94		54.42	1.07
Pile No. 5	do	Pitch pine	21	9.06		13.56	10.52	20.34	31.24	23.92	99.58			1.78

Tie No. 8	do	do	22	12.36	......	9.03	15.21	29.46	13.35	32.91	99.96	......	41.16	1.37
Tie No. 9	do	Baltic redwood	16	9.42	....	6.39	10.38	27.75	31.86	23.51	99.89	......	52.14	1.15
Pile No. 81	Norfolk Creosoting Co	Loblolly pine	11	18.34	....	38.88	13.76	13.12	10.08	24.02	99.86	34.47	37.24	......
Pile No. 82	do	do	15	19.12	......	51.50	12.35	3.74	11.61	21.03	100.23	48.62	34.15	......
Pile No. 83	do	do	7	....	Treated with creosote and resin. Not analyzed.									......
Pile No. 84	do	do	20	8.43	......	13.56	15.78	14.49	19.77	36.13	99.83	......	55.22	......
Pile No. 85	do	do	17	13.21	......	19.07	12.39	12.32	17.58	38.14	99.50	18.96	43.71	......
Tie No. 86	E. B. Cushing, Southern Pacific Co., Houston, Tex.	do	22	[b] 19.36 [c] 16.14	......	22.53	13.47	22.63	18.58	22.37	99.58	22.53	46.18	......
Pile No. 50	International Creosoting and Construction Co., Galveston, Tex.	do	29	17.63	1.26	27.60	22.43	31.22	12.02	5.13	99.66	25.41	48.15	......
Pile No. 51	do	do	29	17.08	2.18	31.06	18.21	36.04	8.17	4.13	99.79	28.14	41.12	......
Paving block No. 52	do	do	34	18.81	.48	26.61	32.06	17.52	8.47	14.42	99.56	......	50.67	......
Paving block No. 53	do	do	29	12.44	.68	17.57	18.78	37.52	16.62	8.56	99.73	3.68	53.89	......
Paving blocks Nos. 54 and 55.	do	do	9	[d] 6.07 [e] 5.46	9.62	14.41	19.27	41.74	11.23	3.40	99.67	......	......	......
Conduit pipe No. 67	Bell Telephone Co	Pine	14	8.74	5.08	27.23	10.46	27.68	19.03	9.93	99.41	23.17	14.28	......

[a] Twenty years as a tie and thirteen years as a fence post.

[b] Center.

[c] Under rail.

[d] Paving block No. 54.

[e] Paving block No. 55.

Glasgow and Southwestern Railway, Scotland:

Tie No. 106 taken out of the Main Line February 12, 1905, near Milliken Park; put in during 1889. Creosoted with 2½ gallons of gas-works creosote of 1.010 specific gravity at 60° F.

Tie No. 104 taken out of the Main Line February 6, 1905, near Elderslie Station; put in during 1887. Creosoted with about 2½ gallons of oil to the tie.

Tie No 113 taken from the Main Line April 16, 1905, near Elderslie Station; put in during 1887. Creosoted that same year with about 2½ gallons of oil to the tie.

Tie No. 109, same history as No. 106.

Great Western Railway, Heath Division, England:

Pile No. 118 was in salt water at New Milford 47 years; not decayed, but attacked by Limnoria.

Tie No. 107 was in sidings at Eastern Depot, Swansea, for 42 years.

Tie No. 105 served for 20 years in the Main Line at Hirwain (Vale of Neath), and afterwards was used as a fence post for 13 years.

Memel pile No. 1 was in a tidal river at Loughor for 53 years. Treated with crude coal tar and not analyzed.

Memel pile No. 2 was in salt water at Llanelly Docks for 58 years. Treated with crude coal tar and not analyzed.

London and Northwestern Railway Company, England:

Ties No. 103 and No. 110 installed in the road for permanent way purposes in 1886; removed February 11, 1905. They were creosoted with blast furnace Scotch oil in 1886.

Northeastern Railway Company, England:

Paving blocks Nos. 88 and 89 removed in perfect condition after being in use at Hull for 20½ years.

Tie No. 114 was under water for 20 years, and afterwards used as a tie under piles of timber in the dockyard for 10 years, a total service of 30 years.

City Engineer, Hull Corporation, Hull, England:

Paving blocks Nos. 90 and 91 laid with close joints in 1894; removed in February, 1905, in perfect condition. Paving block No. 92 consisted of three broken blocks laid with open joints in 1892; not decayed when removed in 1905. Treated with creosote and pitch on the outside; not analyzed.

Maryport and Carlisle Railway Company, England:

Ties Nos. 108 and 137 creosoted in 1881, placed in track 1882, and removed in 1905. Tie No. 137 was not analyzed.

Highland Railway Company, Scotland:

Ties Nos. 2, 3, and 41 were in service in a gravel ballast, damp bed, for 20 years, 20 years, and 22 years, respectively. These ties were seasoned two years before treatment and stacked six months after creosoting before being placed in the track.

North British Railway Company, Scotland:

Tie No. 101 was in the track 21 years; No. 102, 21 years; No. 112, 14 years; No. 100, 14 years (not analyzed). These ties were taken out at different parts of the system.

Clyde Navigation Trust, Glasgow:

Pile No. 116 is from the part of the pile which was above high-water level, and was therefore exposed to the air.

Pile No. 111 is from the part of the pile between high and low water. It was therefore exposed to the wash of the water.

Pile No. 117 is from the part of the pile which was always under water.

Pile No. 4 is from the part which was buried in the ground.

Pile No. 5 is from the part of a pile above high water; creosoted with 8 pounds per cubic foot.

Tie No. 8 was laid in slag in the year 1883.

Tie No. 9 is a part of a Baltic redwood tie laid in 1889. It was bedded in concrete and causewayed over with granite sets. Both of

Clyde Navigation Trust, Glasgow—Continued.

these ties were creosoted with $2\frac{1}{2}$ gallons of gas creosote of not less than 1.010 specific gravity at 60° F.

Pile No. 115 is from the part of pile No. 5 between high and low water; not analyzed; creosoted with 8 pounds per cubic foot.

Norfolk Creosoting Company, Norfolk, Va.:

Pile No. 81, section of a creosoted pile put in Santiago Harbor, Cuba, April, 1887; taken out in perfect condition November, 1902.

Pile No. 82, section of a creosoted pile put in Tampico Bay in May, 1891; taken out in perfect condition October, 1902.

Pile No. 83, section of a pile treated with creosote and resin; removed after seven years badly attacked by Teredo.

Pile No. 84, section of a creosoted pile put in a drydock at Newport News, Va., May, 1881; removed in good condition October, 1901.

Norfolk Creosoting Company, Norfolk, Va.—Continued.

Pile No. 85, section of a creosoted pile in service for 17 years at Newport News, Va.

Tie No. 86 was in the track for 22 years at Houston, Tex.

International Creosoting and Construction Company, Galveston, Tex.:

Piles Nos. 50 and 51 were in Galveston Bay for 29 years.

Paving block No. 52 was in service in the street at New Orleans, La., for 34 years.

Paving block No. 53 was in service in Galveston for 29 years.

Paving blocks Nos. 54 and 55 were in use at Galveston for 9 years. They showed poor service.

Bell Telephone Company:

Conduit pipe No. 67 was in service as conduit at Philadelphia, Pa., for 14 years; removed in perfect condition to make extensions of service.

Approved, April 1, 1907.

James Wilson,

Secretary.

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